Quantitative assessment of C-band and X-band SRTM datasets over the CEOS-WGCV-TMSG test sites and intercomparison of C-band DEM with the OS® PANORAMA DTM

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HRSC Science Team Member (ESA Mars Express 2003)

Overview

- Context: CEOS-WGCV "Terrain Mapping from satellites" Sub-Group (TMSG)
- TMSG test sites - description and location
- Evaluation of SRTM C and X DEMs for UK test site
- Interpretation of SRTM elevation differences:
  - Forest mapping
  - Slope/Aspect effects
  - Mining activities
- Inter-comparison of SRTM DEM products with NextMap
- Use of SRTM for improving ERS-tandem DEMs
- Evaluation of SRTM accuracy and completeness for Spanish test sites
- Conclusions

CEOS WGCV Terrain Mapping

- **What is CEOS WGCV**
  - Committee on Earth Observing Satellites
  - Working Group on Calibration/Validation (Chair: S. Ungar, GSFC)
- **What is the mission of this sub-group?**
  - To ensure that characteristics of digital terrain models produced from Earth Observation sensors at global and regional scale are well understood and that products are validated and used for appropriate applications.
- **What are the specific objectives of this group?**
  - To develop specifications for the generation of '*standardised terrain surface products with known accuracy*' from similar sensing systems in the context of data continuity,
  - to specify evaluation methods and statistics which give transparent information about the *quality and heritage of terrain models*.
  - To produce and update the current dossier of test sites and identify new sites, particularly to satisfy the cal/val requirements of future missions and generally improve access to validation data sets.
- **Why are space agencies interested in topography?**
  - To ensure that geometric and radiometric errors in land products derived from satellites are corrected with the best available data
  - Science requirements covering all the application areas of interest
  - GEOSS social action agenda

Objectives of validation study

- Quality assessment of C- and X-SRTM DEMs using "bare earth" DTMs, high-resolution airborne DSMs and kinematic GPS
- Assess whether they meet the design specification for DTED-1 (Zrms≤18m) and DTED-2 (Zrms≤12m)
- Assess planimetric height accuracy via intercomparisons with "bare earth" DTMs
- Interpret height differences in terms of topographic variables, LANDSAT-derived enhanced vegetation index (EVI) and land cover

Test site Data Sets

Global CEOS WGCV-TMSG test sites

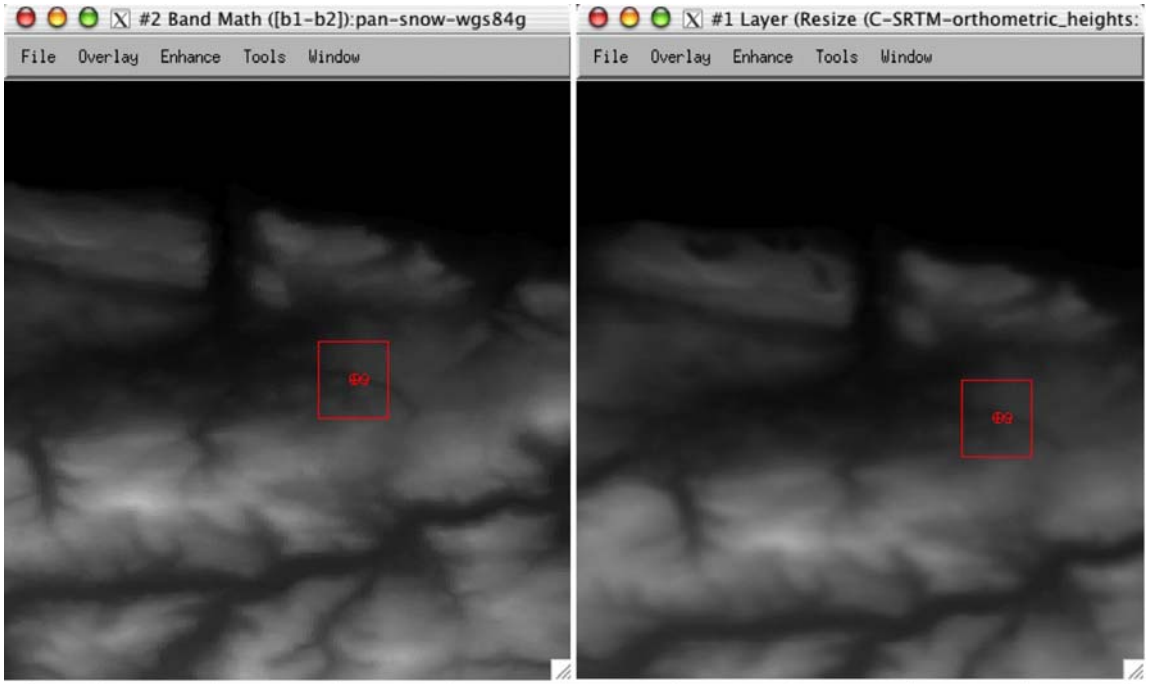
- **Locations:**
  - Snowdonia, UK
  - Catalonia, Spain
  - Aix en Provence, France
  - Bavaria, Germany
  - Puget Sound, WA, USA (data available online from CEOS-WTF at EDC)
- **Criteria for selection based on availability of ground truth and previous use for validation of spaceborne DEMs**
- **Input data sets - most at 1 arc-second (≈30m):**
  - LANDMAP ERS-tandem (UK only)
  - C-Band (3") both JPL unedited and NGA edited (SRTM-DTED®, courtesy of Jim Slater, NGA and EDC prior to public release)
  - X-Band (1" converted to geoid) SRTM DSMs (Snowdonia, Catalonia)
  - Reference Data (DTMs, LANDSAT-7, 5)
  - Stereo optical DEM from Spot1 of Aix en Provence
  - Stereo optical DEMs from SPOT-5 HRS of all 3 non-UK sites
  - NextMap 5m DSM of Snowdonia,UK sub-areas (courtesy of B. Mercer, Intermap)
  - NASA-sponsored lidar DSM and DTM (2m) of Puget Sound

Critical Pre-processing Steps

Global CEOS WGCV-TMSG test sites

- **Initial evaluation using side-side display, Red/Green displays and flickering in ENVI/IDL®, ARCgis® and ERDAS-IMAGINE® showed that there were planimetric shifts between SRTM and "ground truth" DEMs of between 1 to 2 (and occasionally up to 4) DEM grid-cell points (either resampled 50m OS® or 3")**
- **C-SRTM showed an overall translation wrt "ground truth" DTMs (either derived from generalised contours, e.g. OS® PANORAMA® or photogrammetrically derived DEMs)**
- **X-SRTM showed spatially variable higher order effects**
- **Datums checked, kGPS checked and no apparent differences between the different software packages**
- **Shifts also present between Star-3i (NextMap) and C-SRTM whereas there was NO shift with ground truth DTMs or ERS-tandem DEMs or SPOT-stereo DEMs**
- **Initial height difference maps showed that the differences were dominated by these planimetric shifts**
- **After selection of well-distributed GCPs a 1st order polynomial used to warp the two DEMs which removed almost all visible differences**
- **Horizontal shifts also present between JPL unedited SRTM and edited SRTM-DTED® probably due to the effects of thinning vs averaging**

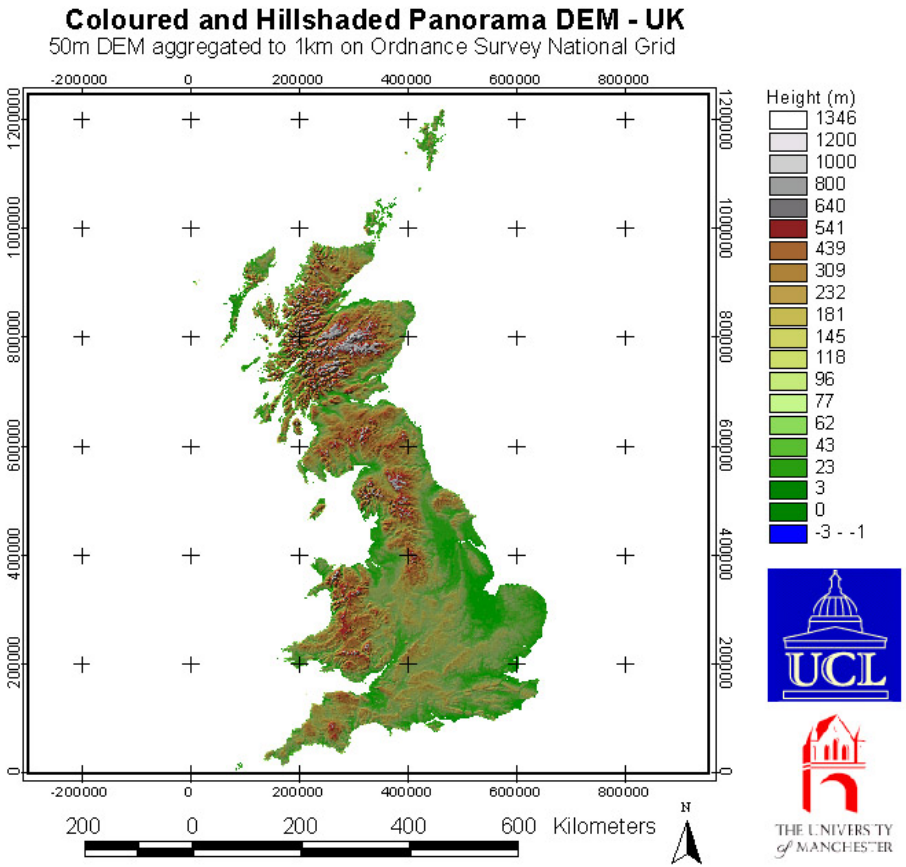
Example of planimetric shifts at GCPs

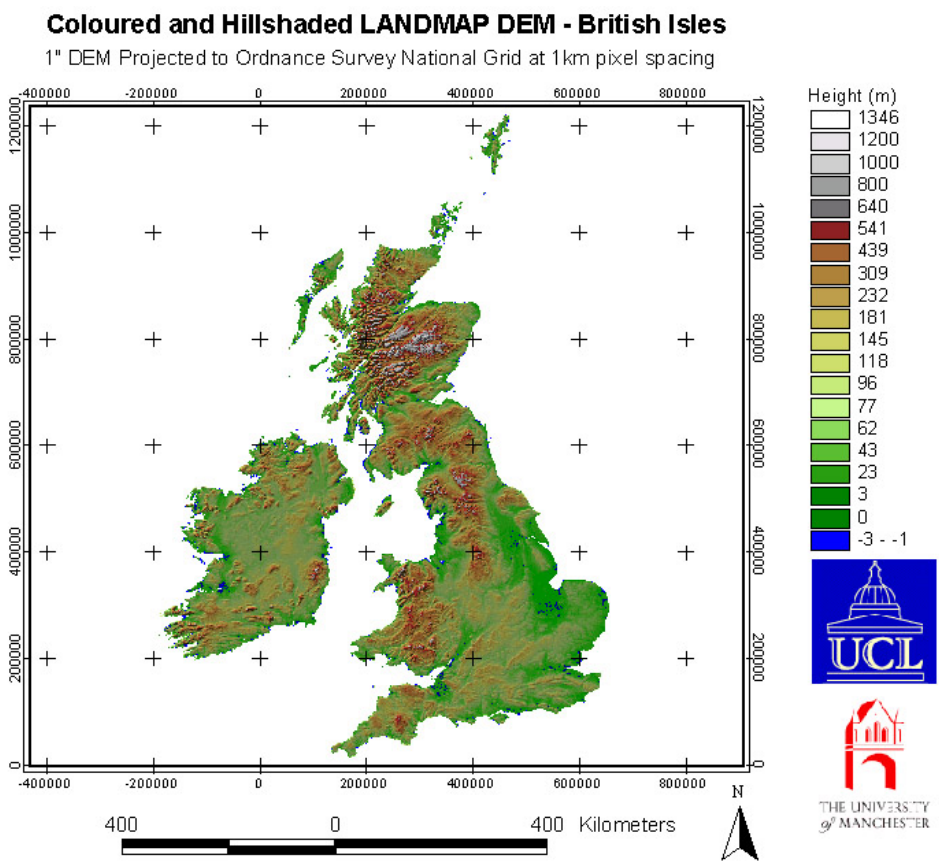


	Base X	Base Y	Warp X	Warp Y	Predict X	Predict Y	Error X	Error Y	RMS
#1+	6875.00	4781.00	6871.00	4781.00	6870.6626	4780.4051	-0.3374	-0.5949	0.6839
#2+	6037.00	926.00	6031.00	926.00	6030.9390	925.3181	-0.0610	-0.6819	0.6846
#3+	3470.00	2322.00	3466.00	2320.00	3464.6627	2320.9518	-1.3373	0.9518	1.6414
#4+	6669.00	2555.00	6663.00	2554.00	6663.5373	2554.3135	0.5373	0.3135	0.6221
#5+	6875.00	4781.00	6871.00	4781.00	6870.6626	4780.4051	-0.3374	-0.5949	0.6839
#6+	4534.00	5142.00	4528.00	5139.00	4529.0210	5140.4894	1.0210	1.4894	1.8058
#7+	1381.00	5283.00	1375.00	5281.00	1374.8641	5280.1685	-0.1359	-0.8315	0.8426
#8+	1155.00	666.00	1150.00	666.00	1150.4237	665.5949	0.4237	-0.4051	0.5862
#9+	4995.00	885.00	4989.00	884.00	4989.2269	884.3535	0.2269	0.3535	0.4201

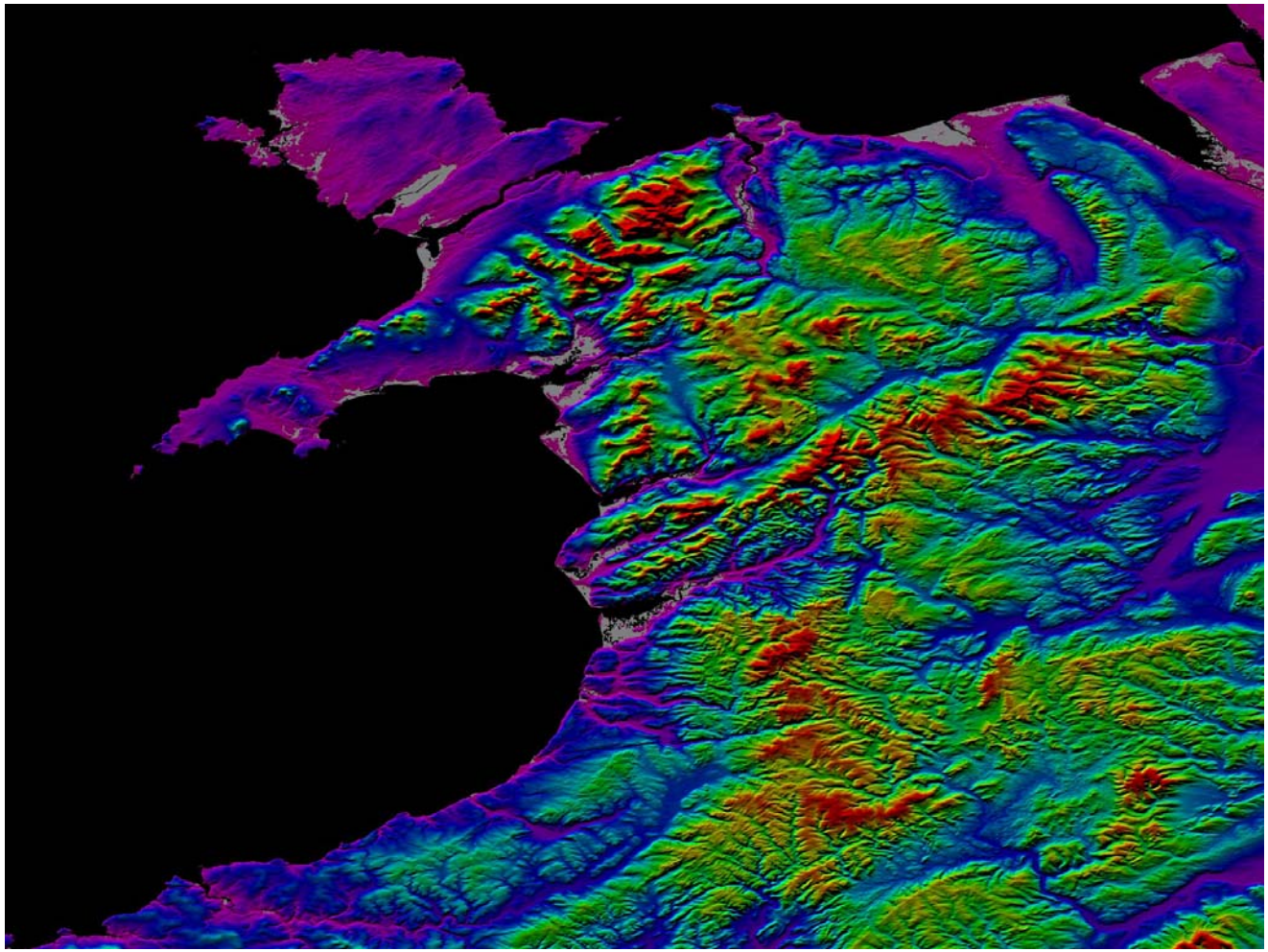
N.B. Initial assessments made using river confluences because of the difficulty in manual measurements.

Intercomparison of OS® PANORAMA® (50m) and LANDMAP IfSAR DEM (30m)

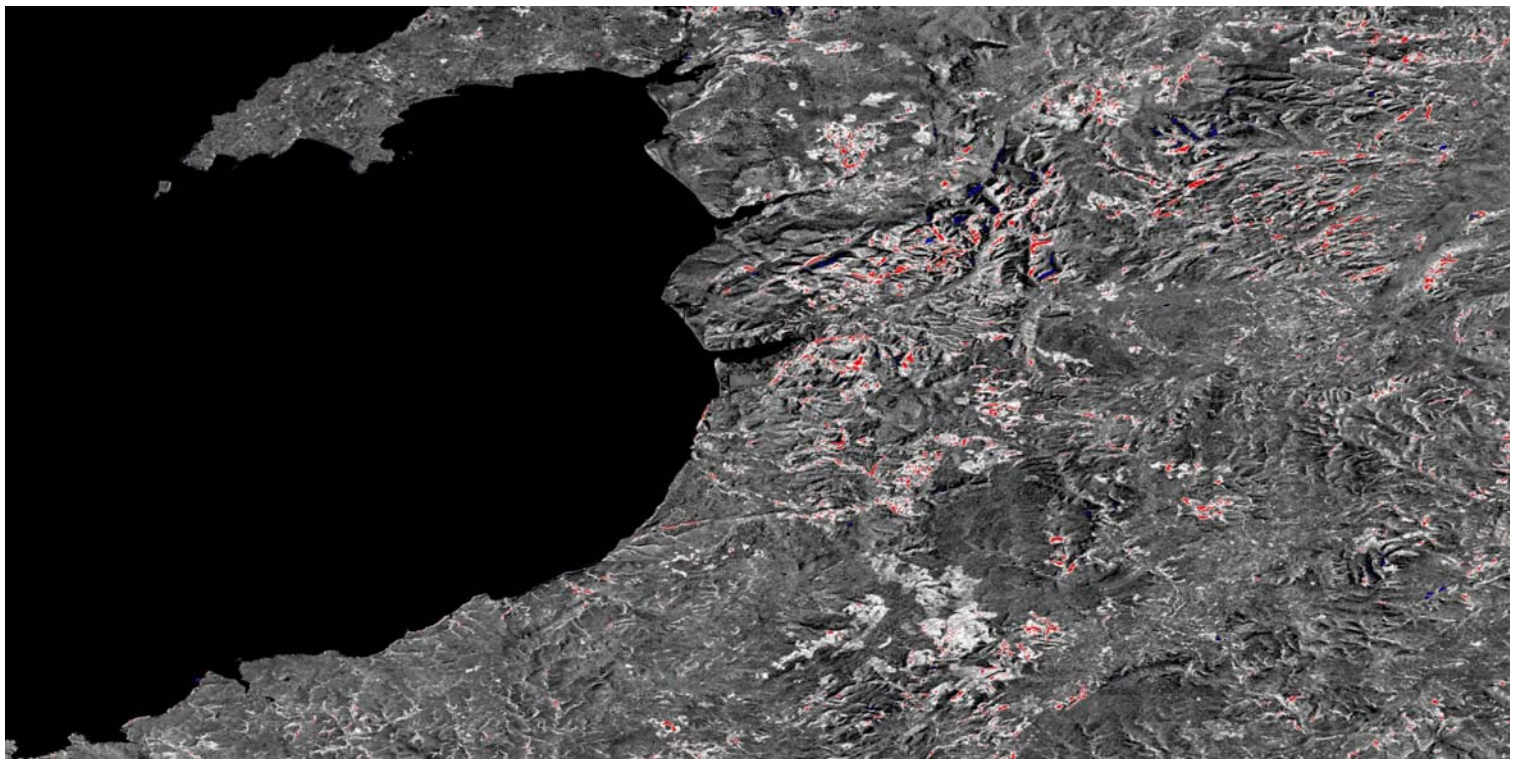




Snowdonia
North Wales, UK - CSRTM DEM



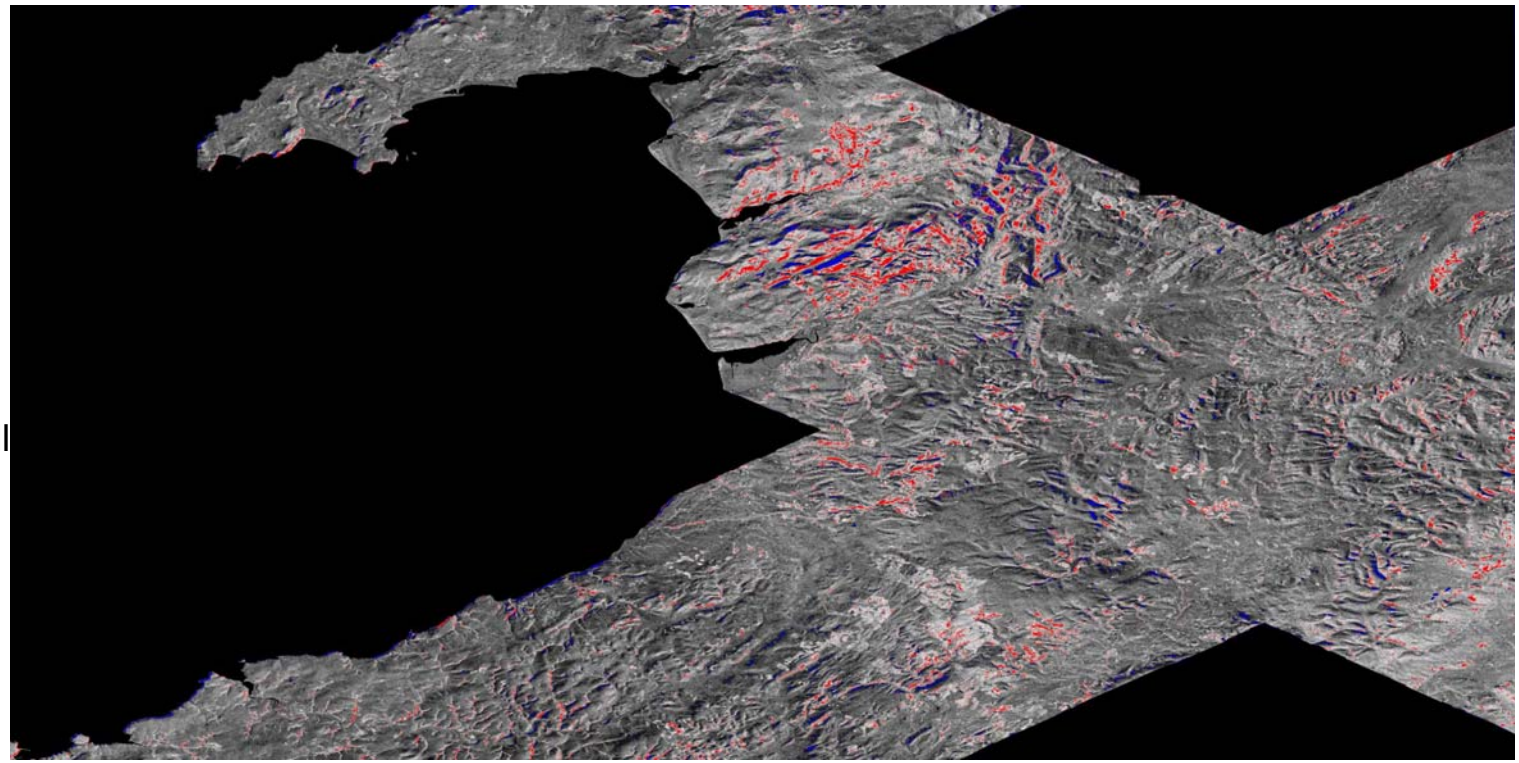
CSRTM-OS®
Red (>17m), Blue (<-17m)
AFTER co-registration using tiepoints and "warping"



Height differences Dominated by: Radar shadows & Forest cover.

1.22±4.13m overall but for DEM differences excluding forest and radar shadow Is ≈1-2m!!

XSRTM-OS®
Red (>17m), Blue (<-17m)
AFTER co-registration using tiepoints and "warping"

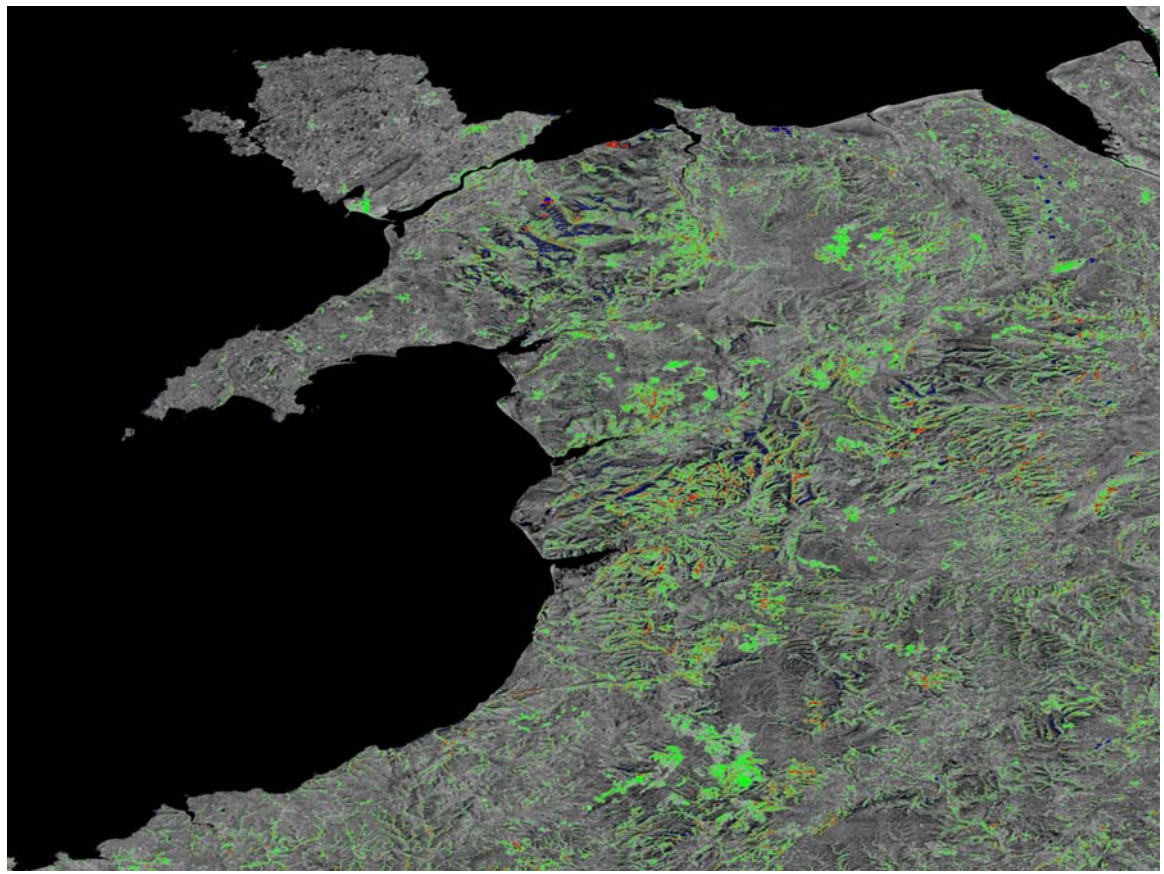


Height differences
Dominated by:
Radar shadows &
Forest cover.

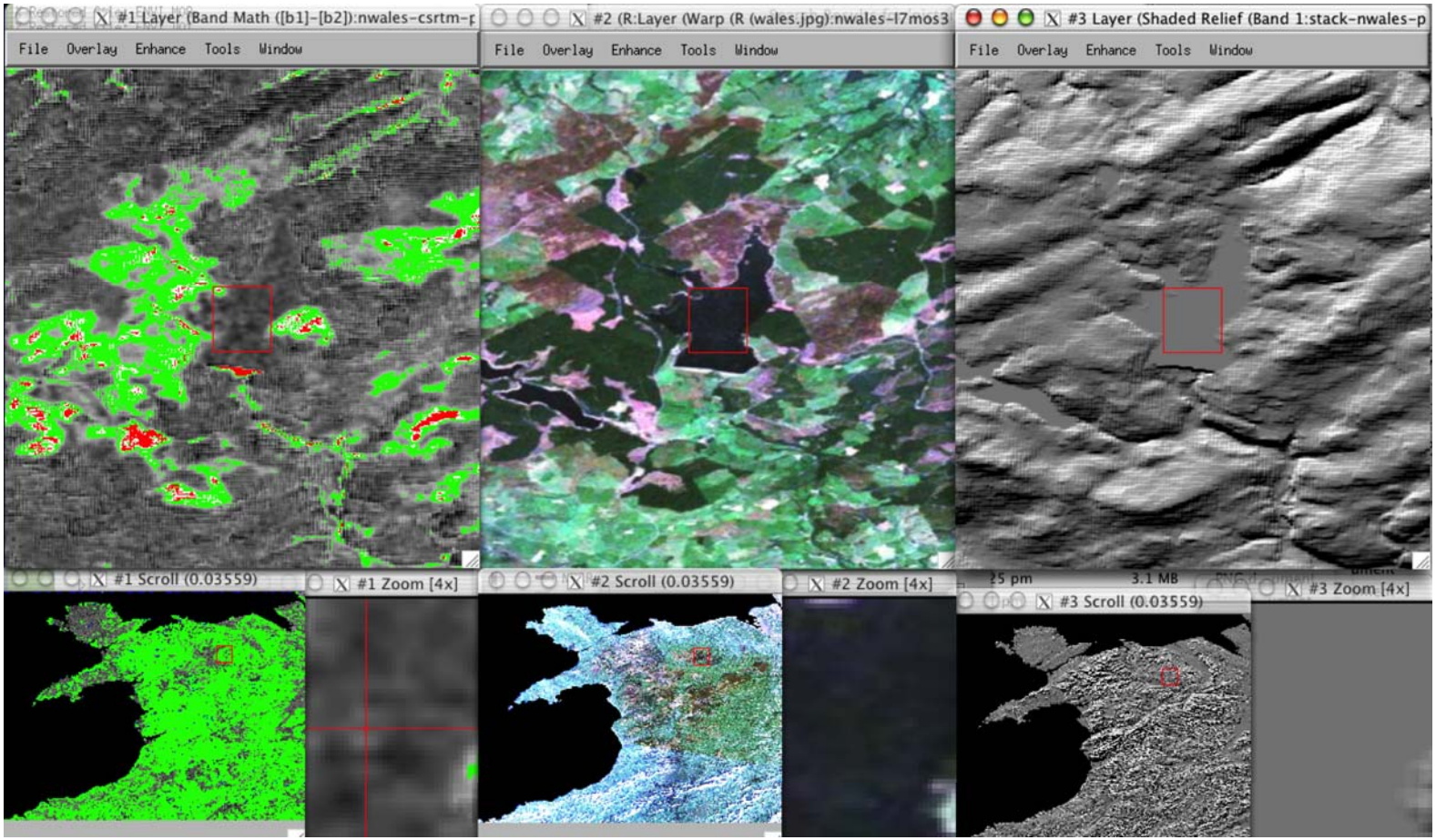
0.26±6.12m overall
Planimetric offsets
spatially variant.

CSRTM-OS®
Green (∂Z=9-16m)

Height differences
in this range are
closely linked to forest cover
In this region



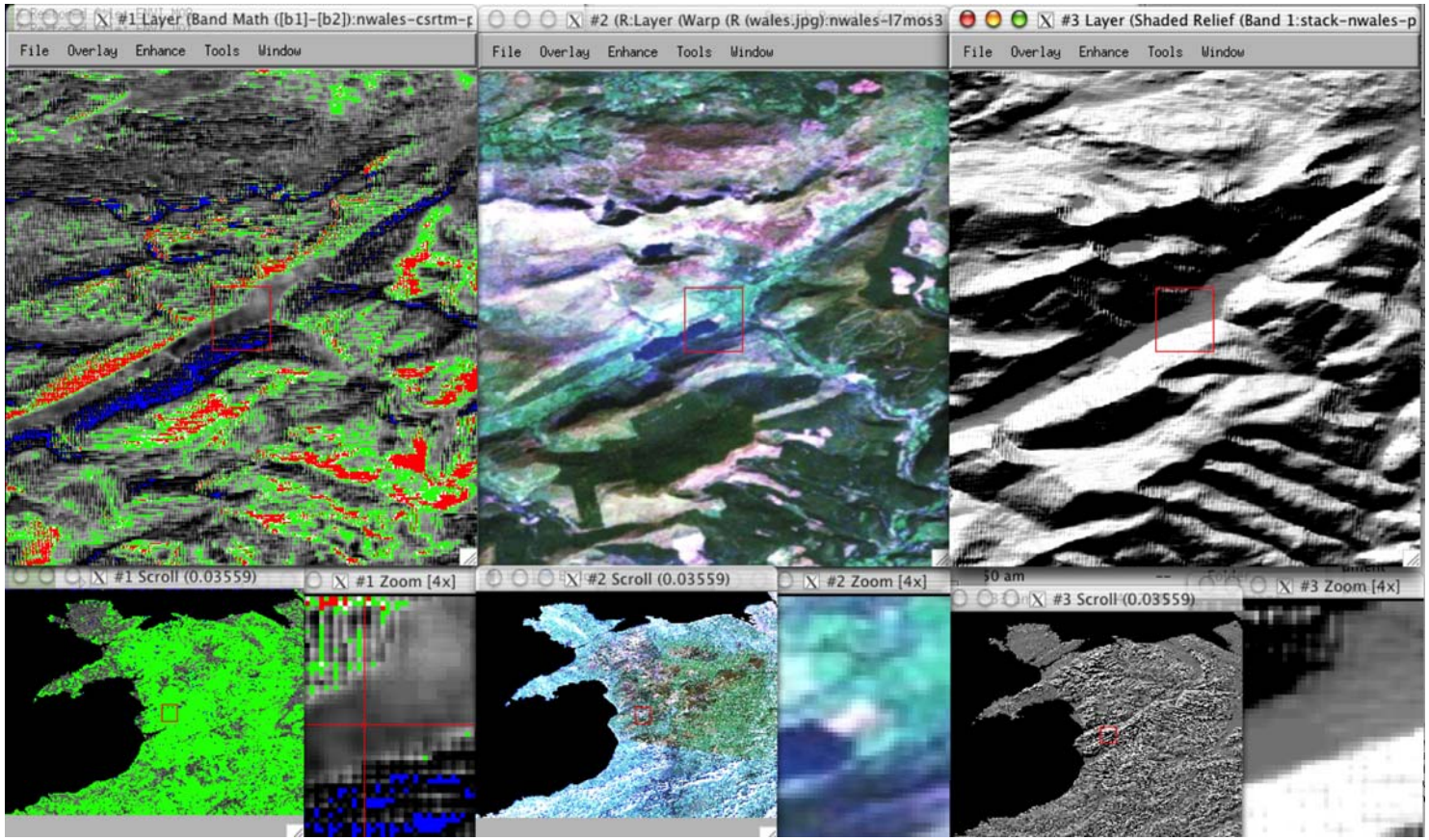
Example area showing impact of forest cover (Green=∂Z=9-16m)



CSRTM-OS® Landsat 7 (3,2,1) OS® PANORAMA®

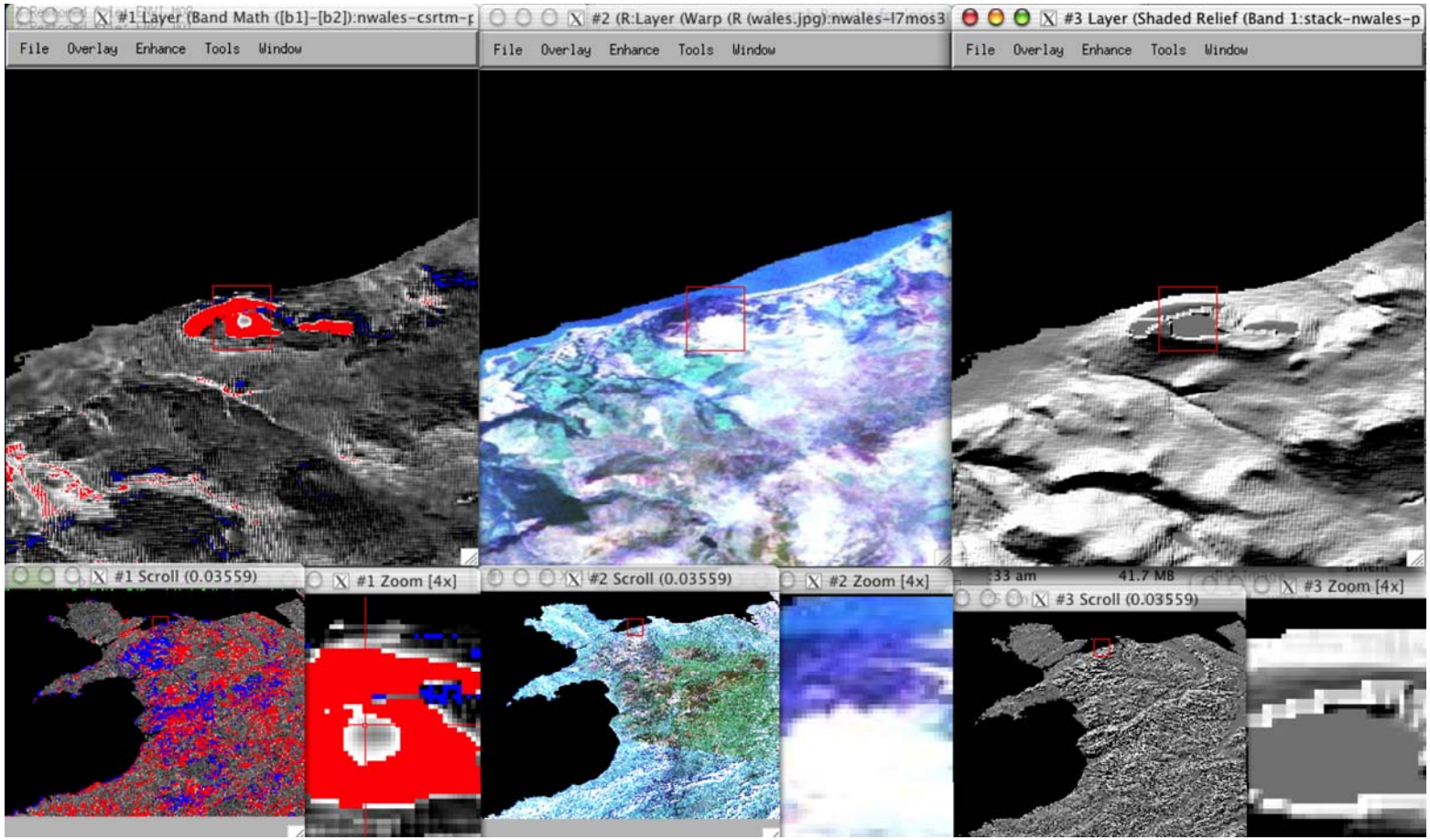
Example area showing impact of slope/aspect + forest cover

N.B. Limited examples of Slope/aspect effects. Cannot unscramble these due to impact of mosaicing of multiple “looks”



CSRTM-OS® Landsat 7 (3,2,1) OS® PANORAMA®

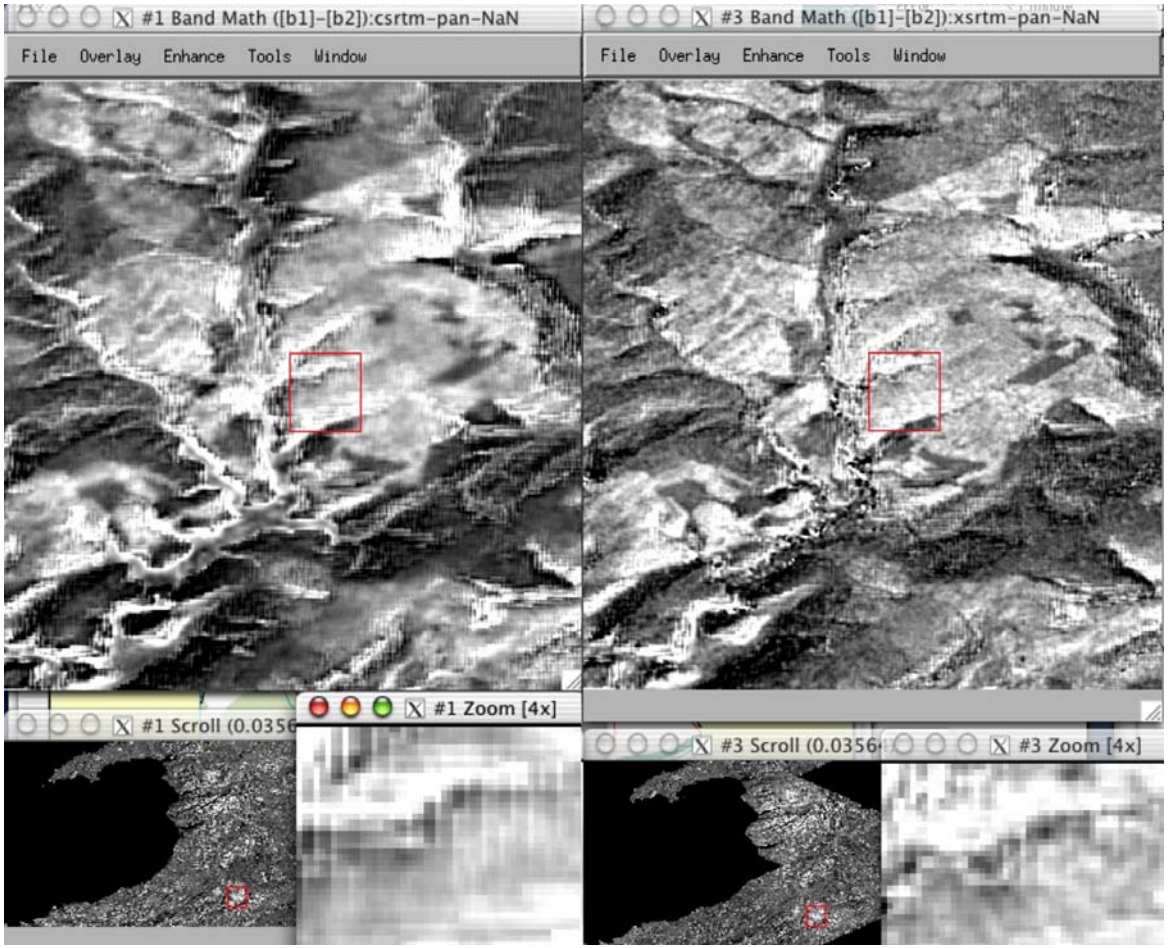
Example of landscape change from CSRTM-OS®: Mining Activities



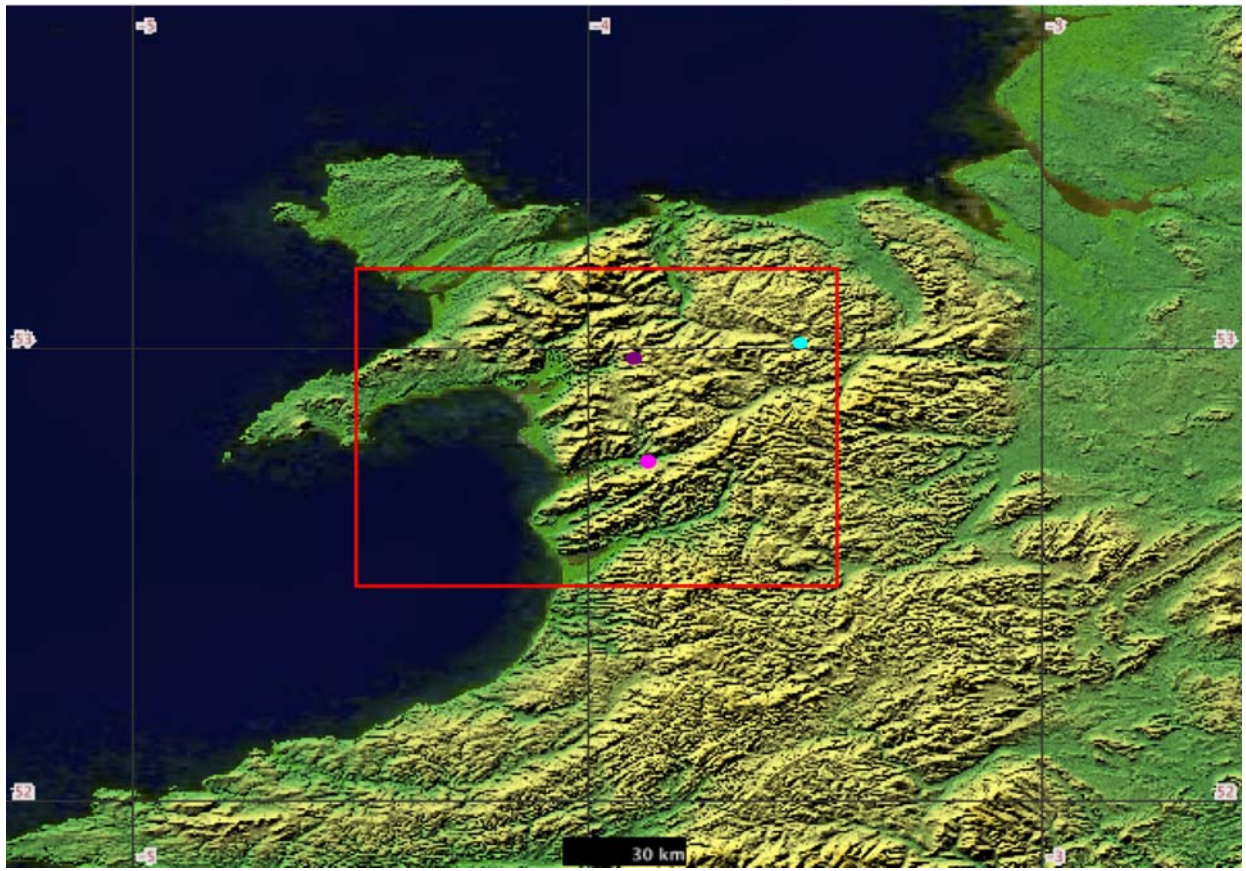
CSRTM-OS® Landsat 7 (3,2,1) OS® PANORAMA®

Intercomparison of CSRTM-OS® and XSRTM-OS®

N.B. 1” XSRTM and 3” CSRTM differences with OS® DTM show little substantive differences. Little radar penetration at CSRTM for this area.

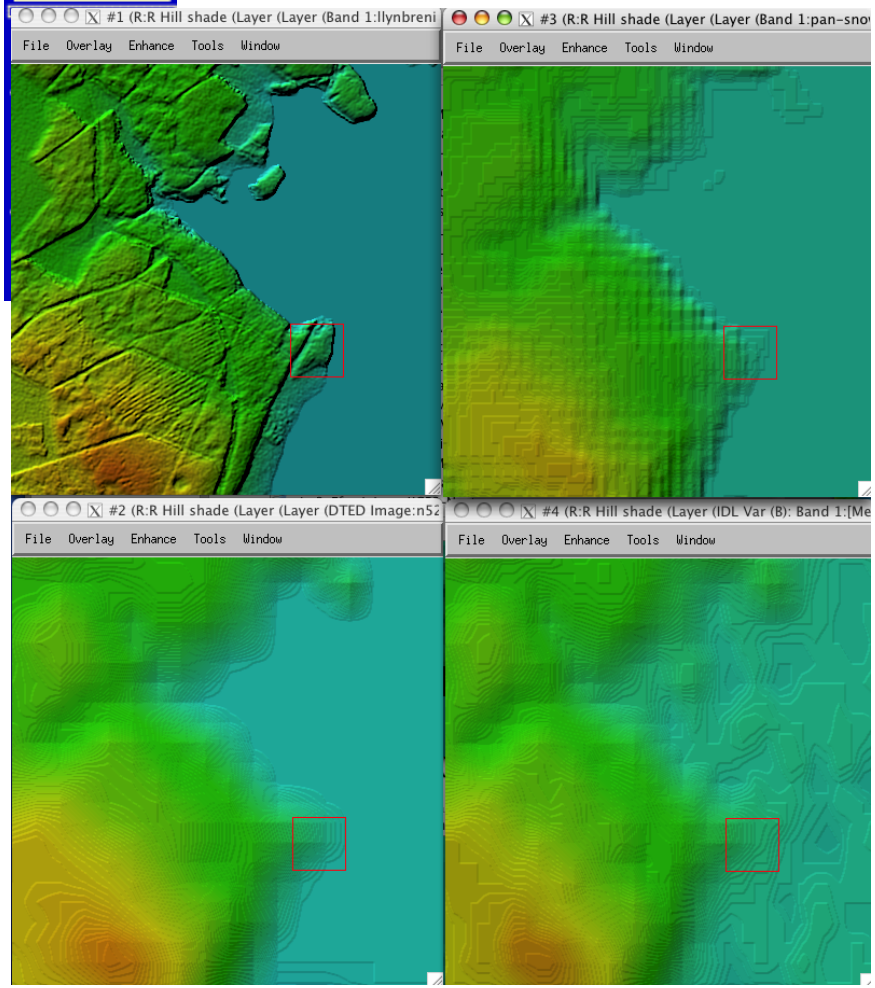


North Wales test-sites for NextMap® DSMs



N.B. Three coloured dots refer to three 10 x 10km NextMap test areas (courtesy of B. Mercer,InterMap technologies). NO co-registration performed

Summary of inter-comparison stats



NextMap (UL), OS PANORAMA (UR), SRTM-DTED1 (LR), JPL-SRTM (LR)

LlynBrenig

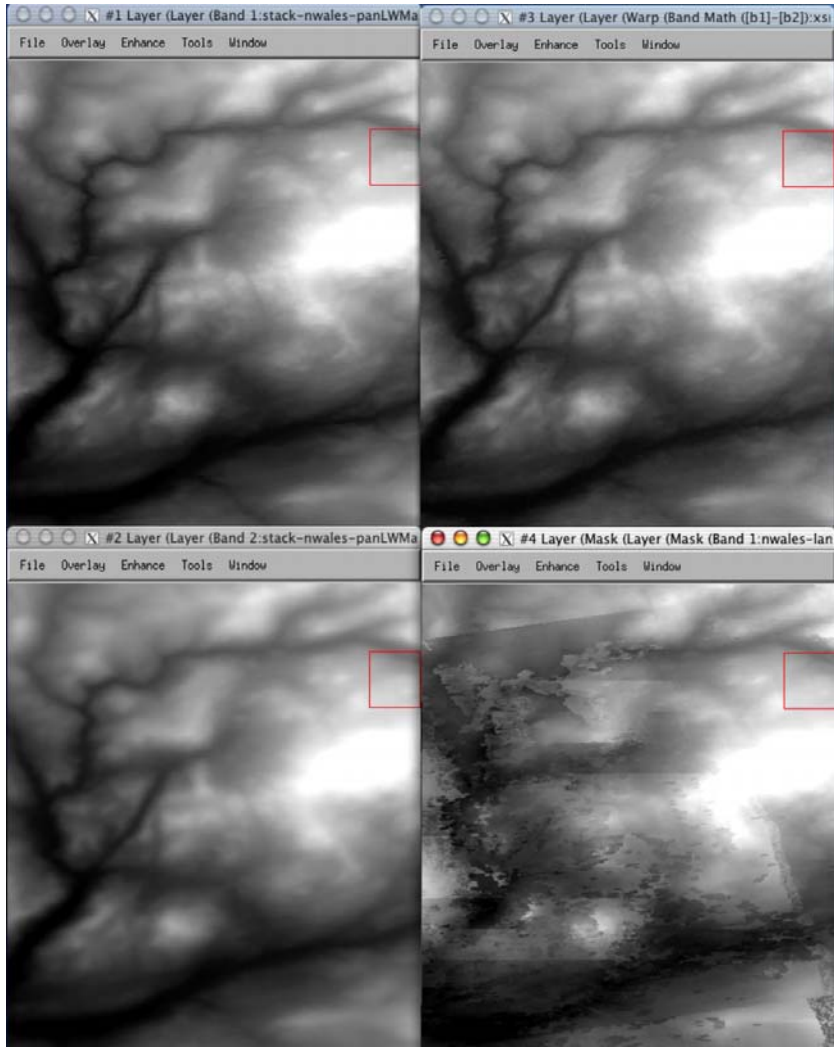
Minffordd	Min	Max	Mean	Stdev
NextMap-PAN	-94.22	85.33	5.73	16.29
JPL-PANORAMA	-701.00	154.00	2.27	35.88
DTED-PANORAMA	-717.00	134.00	2.28	29.84
JPL-DTED	-482.00	698.00	0.07	10.37
JPL-NextMap	-712.16	125.61	-3.45	28.20
DTED-NextMap	-738.42	102.61	-3.44	23.31

LlynBrenig	Min	Max	Mean	Stdev
NextMap-PAN	-54.75	47.07	-4.43	7.37
JPL-PANORAMA	-160.00	63.00	3.07	11.32
DTED-PANORAMA	-50.00	57.00	3.13	9.48
JPL-DTED	-161.00	17.00	-0.06	2.46
JPL-NextMap	-176.79	50.82	-1.36	9.01
DTED-NextMap	-50.45	43.39	-1.30	7.37

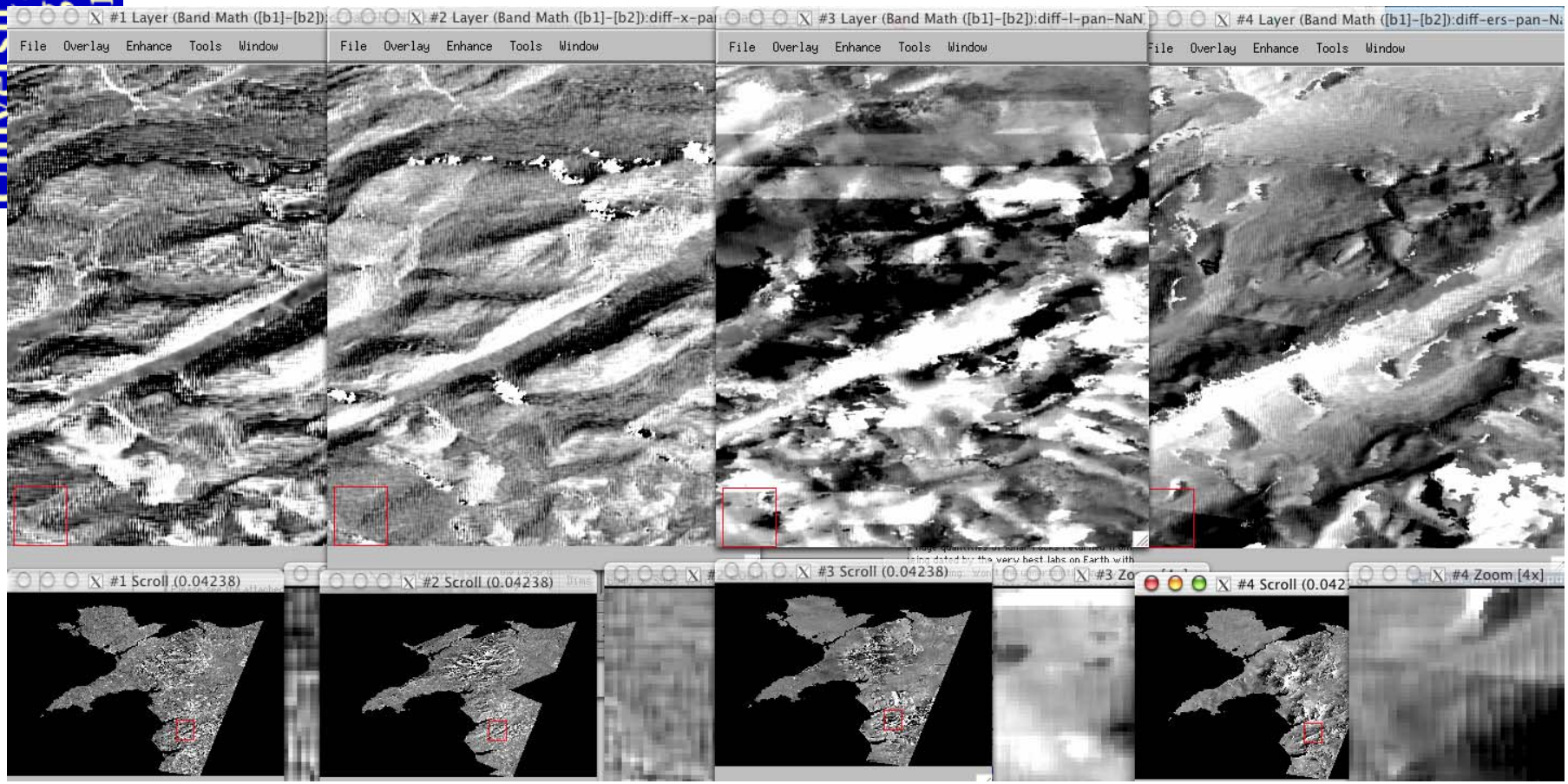
Ffestiniog	Min	Max	Mean	Stdev
NextMap-PAN	-74.46	46.47	-3.50	7.50
JPL-PANORAMA	-93.00	100.00	5.31	14.48
DTED-PANORAMA	-80.00	82.00	4.45	12.19
JPL-DTED	-19.00	23.00	0.86	2.76
JPL-NextMap	-72.90	74.66	1.82	10.46
DTED-NextMap	-62.36	63.66	0.95	8.52

Inter-comparison of SRTM and LANDMAP

- Little difference between OS® (UL), X-SRTM (UR) C-SRTM (LL)
- ERS-tandem LANDMAP (LR) shows strong atmospheric artifacts and blocking due to phase unwrapping methods (MCF)
- SRTM DEMs were then employed for phase reference for ERS-tandem for subsequent processing.



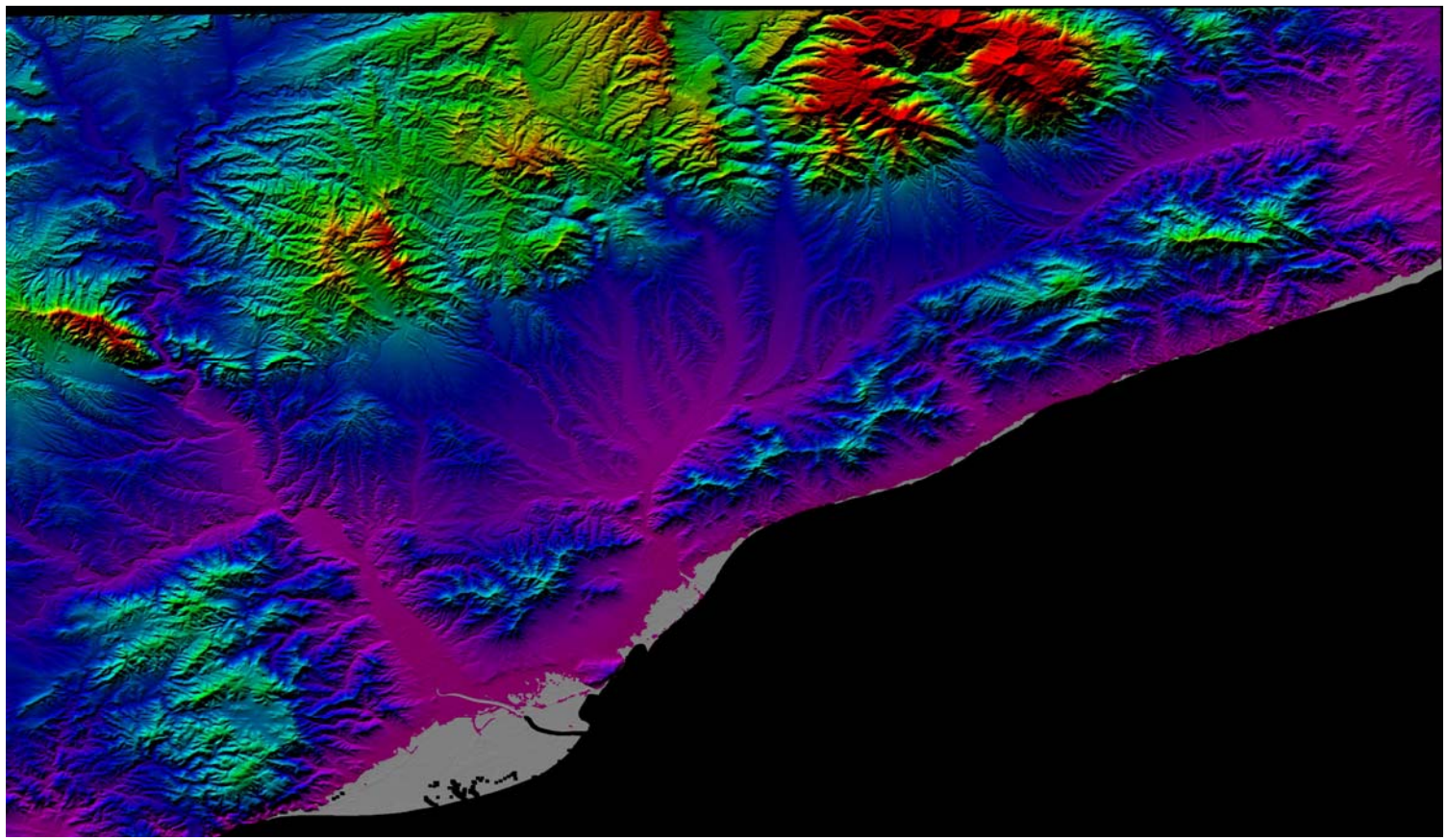
Use of C-SRTM for densifying ERS-tandem to 30m Some impact on minimising atmospheric and blocking artifacts.



CSRTM-OS®	XSRTM-OS®	LANDMAP-OS®	ERS(SRTM)-OS®
0.59±3.16m	0.04±5.74m	-0.1±17.92m	-0.11±11.36m

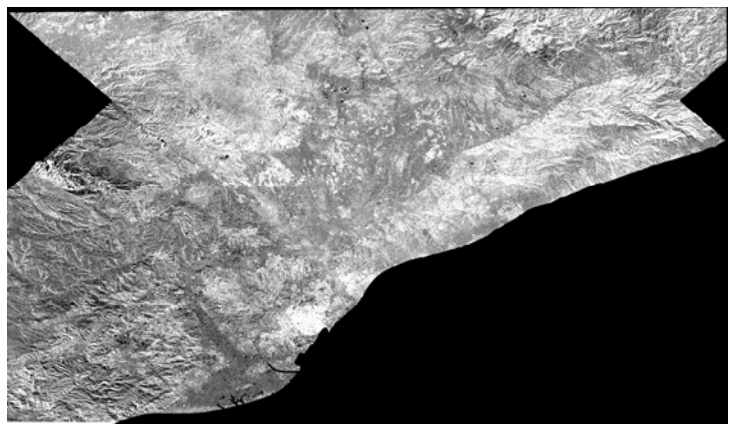
Ground Truth 2

Test Site Catalonia/Barcelona
15m photogrametric DTM (±1.1m)
Courtesy of W. Kornus, ICC, Barcelona



Intercomparison of C- and X-SRTM DEMs with reference DTMs

- **CSRTM-reference(Upper Right) = 3.44±5.78m**
- **XSRTM-reference (Lower Right) = 4.32±6.63m**
- **Note correlation of forest with POSITIVE height differences**

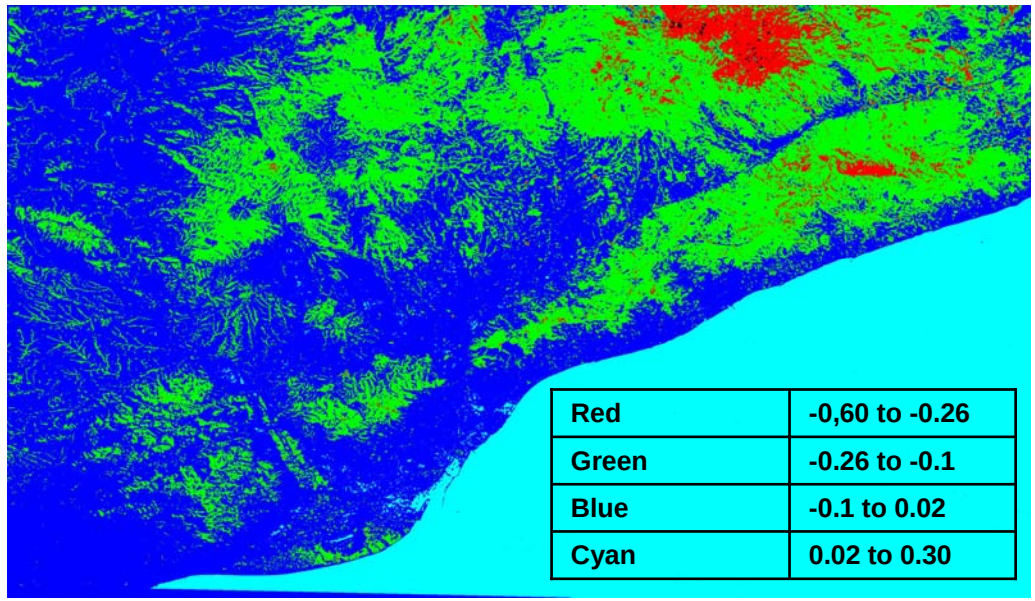


Courtesy of Dietmar Backes

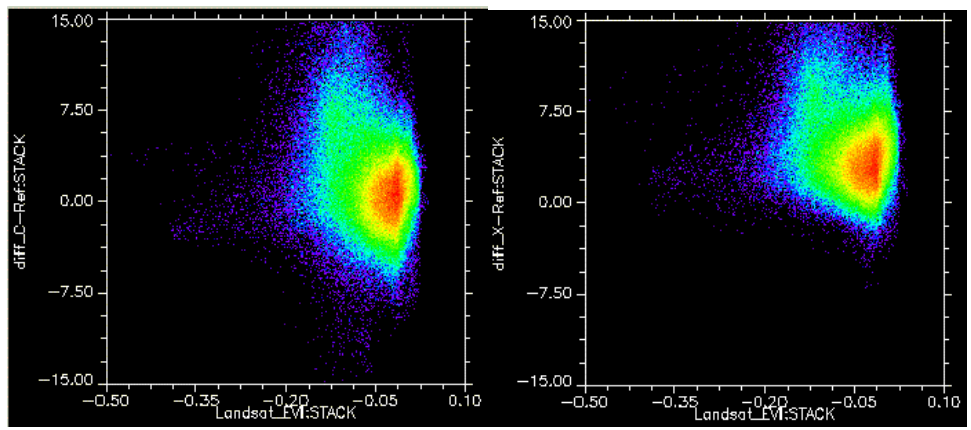
Assessment of the relationship of height difference to EVI

$$EVI = \frac{r_{NIR} - r_{Red}}{r_{NIR} + C_1 r_{Red} - C_2 r_{Blue} + L} \times G$$

- For MODIS, MERIS and LANDSAT use
- L=1, C1 = 6, C2 = 7.5, and G (gain factor) = 2.5
- Cluster of EVI in range -0.26 to -0.1



Red	-0,60 to -0.26
Green	-0.26 to -0.1
Blue	-0.1 to 0.02
Cyan	0.02 to 0.30



C-ref vs EVI

X-ref vs EVI

Conclusions

- C-SRTM and X-SRTM elevation differences for Snowdonia test site:
  - 1.22±4.23m (CSRTM - OS®) cf. 0.26±6.12m (XSRTM-OS®)
  - -0.1±17.92m (LANDMAP-OS®) cf. -0.11±11.36m (LANDMAP-OS®/C-SRTM)
- C-SRTM and X-SRTM elevation differences for Barcelona test site.
  - 3.44±5.78m (CSRTM - reference)
  - 4.32±6.63m (XSRTM- reference)
- Vertical Accuracy much higher than original specification (Zrms≤18m) and DTED-2 (Zrms≤12m).
- Height differences for SRTM correlated to
  - forest cover and EVI
  - Slope/aspect wrt radar look direction
- Horizontal accuracy appears NOT to meet specifications for all 4 European test sites (90-360m)
- Co-registration issues remain for CSRTM with national DEMs but more severe for XSRTM possibly due to single swaths (lack of multiple imagings)
- Use of SRTM DEMs can reduce RMS in ERS tandem DEMs but some atmospheric and blocking artifacts remain
- Further research to assess how"bare earth" DTM can be extracted from SRTM DEMs and penetration depth of C-SRTM using lidar DSM/DTMs